NATURAL GAS STORAGE WORKSHOP

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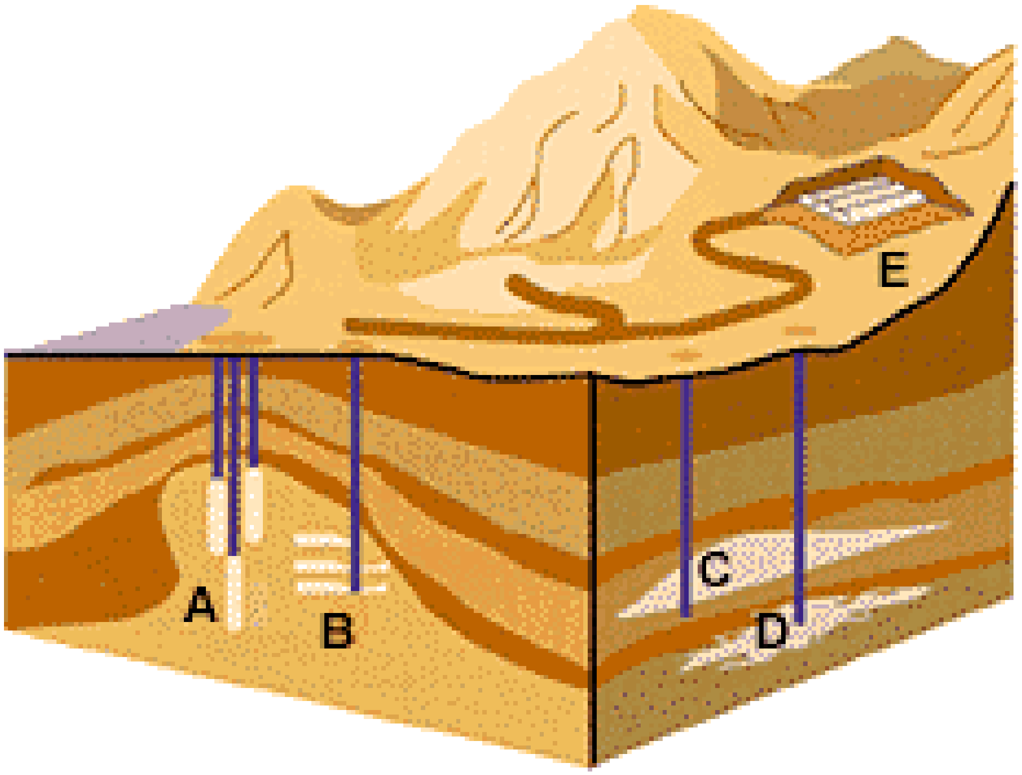

Resources for underground storage include (A) salt caverns, (B) mines, (C) aquifers, (D) depleted reservoirs, and (E) hard rock caverns. Source: http://www.fe.doe.gov/oil_gas/gasstorage/

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Overview

The U.S. Department of Energy's National Energy Technology Laboratory (DOE/NETL) hosted a one-day collaborative workshop on Natural Gas Storage Research and Development in Pittsburgh, Pennsylvania, on November 29, 2001. The purpose of the workshop was to develop a roadmap of the technologies needed to improve conventional storage field performance and to supply the anticipated demand for natural gas to fuel power generation plants using advanced storage concepts. Participants were asked to recommend priorities for natural gas storage R&D and to explore ways in which DOE can collaborate with industry and others to accomplish priority R&D in public/private partnerships.

Forty-five representatives representing a cross-section of interests and expertise from industry and academia participated in the workshop. Discussions of technology challenges, needs, and actions took place in three separate groups. Two groups focused on conventional storage issues, while the third group concentrated on gas storage for power generation. Each group developed a list of challenges and barriers to improved natural gas storage. Participants then developed opportunities for research and development that could provide means of overcoming these barriers. The top five research and development needs were selected through a consensus process, and implementation strategies were developed for each. The preliminary results of the workshop are provided in this document.

The information gathered on industry's technical challenges and needs will help provide a foundation for a roadmap to guide natural gas storage R&D in industry and government and to guide R&D solicitations. Identifying and developing these solutions will ensure that the U.S. natural gas storage infrastructure will continue to meet the needs of consumers for decades to come.

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Section I
Conventional Gas Storage – Group A

Exhibit 1-1. CONVENTIONAL GAS STORAGE – GROUP A: Technology Barriers to Improved Natural Gas Storage

Reservoir Characterization	Damage at Wellbore and Injectivity	Reservoir Management	Changing Market Conditions	Salt/Rock Caverns	Drilling Technology	Integrity
Cheaper 3-D seismic	Lack of chemical, minimally intrusive diagnostic techniques to accurately identify good stimulation candidates	High levels of cushion gas to cycled gas	Strategically located underground space	Availability of cost-effective storage (salt, depleted reservoir)	Greater use of multi-laterals: cost vs. short term benefits	Ability to make integrity decisions for aging infrastructure
Seismic or other technology to better identify gas filled porous bodies in reefal structures	Determination of when/where damage occurs (injection vs. withdrawal vs both)	Lower cost cushion gas replacement	Injection season is too long	Effect of surrounding pressures on production from salt caverns	Horizontal drilling technology for hard rock reservoirs	Determining gas loss and migration beyond dry hole perimeter
Formation properties such as heterogeneities not well characterized	Non-Darcy (i.e., turbulent) skin damage in high rate storage wells limits peak rates (turbulent flow in reservoir)	Quantify the pressure limits in a reservoir	Proper valuation of different storage services	Salt cavern brine disposal		Low cost, nonintrusive method of measuring downhole cathodic protection
Mechanical and hydrological characterization of rock mass	Reduce cost of wellhead filtration	Improvement of working gas to base gas ratio in aquifers	Conservative nature of LDC's – low tolerance of risk – high storage balances	Lined rock caverns – Tunneling techniques		
Geological assessment of southeastern U.S. structures compatible with storage	Find best technology to best remove skin damage in wells	Low cost H_2S removal	Transmission infrastructure into/out of new storage			
Low cost, 4-D seismic or other method to identify gas in-pace at end of season	Improve well injectivity	(Deliverability) – understanding gas hydrates	Limited research and expertise in transition from cryogenic to conventional storage			
Logging horizontal wells	Application of frac pac technology to thick, high permeability, unconsolidated sandstone reservoirs.	Low cost, low O&M measurement and control technology for individual well pressure and flow measure, with oil, water, sand (+/- 10%); remote control	Cost – No low hanging fruit – Deliverability needed – Volatility supports – At risk			
Differences in flow properties of gas during injection and production, i.e., hysteresis not well understood		Injection – Cycling required in future – Maintenance/supply				
		Accurate assessment of full field potential to optimize working gas, feeding value, etc.				
		Inventory verification – Accurate method – Little downtime – No time for shut-in				

Exhibit 1-2. CONVENTIONAL GAS STORAGE – GROUP A: R&D Needs to Overcome Barriers

Most Critical R&D Needs: ✪ = High Priority Vote ● = Priority Vote

Reservoir Characterization		Reservoir Management	Gas Processing	Damage at Wellbore and Injectivity	Remote Sensing and Control
Seismic technology applications – Working gas/Base gas ratio improvement – Accurate characterization using 3D seismic simulator – Monitor reservoir – Illuminate periodically – Implement plan ✪✪✪✪ Develop alternative to surface seismic to identify by-passed gas – Minimize impact on community – Low cost/quick ✪●● Tie in real time pressure/rate data to build computer reservoir model ●● Better/lower cost cross-well seismic Research into techniques that enable seismic data to be reprocessed to identify reservoir characteristics Develop better numerical simulators to handle heterogeneities—hybrid FD/FE/BE simulators ●●	Development of process that combines geophysical in-situ and lab testing with proper models to characterize rock mass ● Laboratory study of permeability hysteresis for gas flow ● Test and analysis progress to deformation near wellbore coupled mechanical/fluid deformation short/long term ● Understanding of transition between continuum – discontinuum response of rock mass time and length-scale ● Develop cheaper rotary sidewall coring tool that reliably operates in air and in hard rock without overheating (and in cased hole) ● Research/fabrication/ testing of smaller more flexible logging tools for use in horizontal well bores ● Application of ground penetrating radar	Reversible downhole barrier to gas migration (foam, polymers) ✪●●●● Explore using reservoir limits test technologies to replace S/I's for inventory monitoring ●●●●● Remote sensing of migrated gas ●●●● Computer model to accurately predict inventory—no shut-in required ● Study dual-use of storage—liquid and gas, seasonal?	Develop means of preventing/dealing with hydrates formed during operations ✪✪●●●● Reduce cost of wellhead filtration ●●●●● Better final cleaning procedure for the injecting steam—electrostatic? Or any other ● Designing and testing of hydrogen removal equipment geared to smaller storage operations Reduce cost of compression	Sampler or recorder to determine type and extent of wellbore damage ✪✪ Develop testing methods for skin damage determination in caverns as opposed to wells (caverns and wells) ●●● Prevention of damage – Recommendation/ best practice already in existence – Study for damage issues not dealt with by best practices/economics ●●● Prevent deliverability loss due to water encroachment (relatively permanent damage) ●●	Electronic flow measurement – non-intrusive rate measuring device that does not require extensive facilities and can handle multiple phases ✪✪● Downhole pressure measurement-develop wireless communication technology that requires minimal energy so downhole sensors can communicate with surface recorders over extended periods (months, years) ●●● Electronic flow measurement-communication -cheaper, more reliable communication technology that does not require line-of-sight for communication ● Less expensive instrumentation/ control equipment for reservoir management

Exhibit 1-2. CONVENTIONAL GAS STORAGE – GROUP A: R&D Needs to Overcome Barriers *(continued)*

Most Critical R&D Needs: ✪ = With Major R&D Component ● = With Minimal R&D Component

Salt/Rock Caverns	Integrity	Drilling Technology	Other
Proof of concept scale test heat transfer of LNG to brine ✪●●●● Develop new salt production (from brine) technologies ●● Research tunneling in other countries ● Alternative method to remove salt for cavern formation—heat? Develop brine concentration method to reduce injection volume (inexpensive)	Better means of assessing remaining strength. Better means of measuring metal loss. ✪✪●●●● Device to measure current flow downhole. Application of pipeline current mapping device ●	Reduce cost of drilling workovers – Lasers? – Conventional ●●● Horizontal drilling in hard rock Directional hammer bit with	Expedited processing of governmental approvals for pipeline expansions Promotion of frontier supply areas (and improved drilling techniques) to provide adequate supply for injection.

Exhibit 1-3. CONVENTIONAL GAS STORAGE – GROUP A: Implementation Strategy

R&D Priority	Component R&D Activities and Steps	Capabilities, Tools, Facilities, and Resources	Collaborations, Partners, Government Role	Geographic Benefits	Impact (0-5)
Use seismic and alternative technologies for better reservoir characterization and monitoring for better working gas to base gas ratio	Develop full cycle model Benchmark/Baseline review Hardware development Software development Research on more controllable seismic sources Improve resolution Tailor to natural gas storage needs Build simulator Integrate current ind. Technologies to attack problem Non-surface seismic=>alternative, non-invasive	Candidate reservoir Geophysicists Modeling expertise Remote sensing capabilities	Universities => interpretation Industry: storage (data) Geophysical companies Oil/E&P companies Military expertise (national/defense labs) Government Role – Funding – Technology sharing	Wide-spread Largest: areas w/ existing reservoirs and some new	Deliverablity/Cycling = 3.5 Cost Savings = 4.5 Safety and Security = 1 Capacity = 5 Environmental = 1.5 Reliability = 3
Develop a down-hole barrier to gas migration	Study barrier placement Location criteria Material/chemical studies Accurate reservoir characterization Monitoring techniques	Physical chemistry expertise Lab testing Test reservoir	Storage operating company Academia Well service companies Chemical companies Waste remediation companies Government Role – Funding – Apply waste experience (technology sharing)	Widespread Especially aquifer operations	Deliverablity/Cycling = 2 Cost Savings = 3.5 Safety and Security = 3 Capacity = 5 Environmental = 3 Reliability =3

Exhibit 1-3. CONVENTIONAL GAS STORAGE – GROUP A: Implementation Strategy *(continued)*

R&D Priority	Component R&D Activities and Steps	Capabilities, Tools, Facilities, and Resources	Collaborations, Partners, Government Role	Geographic Benefits	Impact (0-5)
Develop a method to prevent/handle hydrates formed during operations	Basic chemistry & thermodynamic studies Computational flow/fluid dynamics Sensing technologies Phase behavior	Basic chemistry Lab test facilities Flow loop Field test	CFD consortium Chemical companies Academia/universities Storage field operator Government Role – Funding – Technology sharing	Especially cold climates High pressure reservoirs	Deliverablity/Cycling = 2.5 Cost Savings = 3 Safety and Security = 3.5 Capacity = 0 Environmental = 0 Reliability = 5
Develop brine disposal method	Disposal studies Alternative uses/by-products Small volume salt production Geologic studies Technology adoption/transfer	New salt production technology Geologic studies Geologic characterization Reservoir characterization	Salt industry Gas storage operators Liquid storage operators Oil producers Government Role – Funding – Government regulatory cooperation – Incentives – Facilitator	Northeast (W. NY, W. PA) Michigan Central AZ	Deliverablity/Cycling = 4 Cost Savings = 5 Safety and Security = 0 Capacity = 2 Environmental = 2 Reliability = 0
Develop method to better assess metal loss and remaining strength	Look at line pipe studies Process piping thickness surveys Metallurgy studies Gather info/data from operators that have done studies Burst testing	Correlation modification to fit down-hole pipes Lab to perform burst test	Storage field operator Well service companies Corporate/industry labs Universities National labs Regulatory assistance Collaboration with national labs Funding Objective evaluation of cap.	Widespread	Deliverablity/Cycling = 1 Cost Savings = 4 Safety and Security = 4.5 Capacity = 0 Environmental = 4.5 Reliability = 4

Section II
Conventional Gas Storage – Group B

Exhibit 2-1. CONVENTIONAL GAS STORAGE—GROUP B: What are the Barriers to Improve Conventional Gas Storage?

Reservoir Characterization	Market Uncertainty/ Risk	Integrity	Existing Facilities	Regulations	Other
Extending peaking ability from conventional reservoirs Some converted wells are not properly spaced; optimum well spacing Lack of production methodology for water/gas flow in aquifer storage Need better brine disposal Lack of method of brine water disposal for salt projects Need for information and analysis quicker; data availability Need to get expertise in reservoir model in right hands Lack of reservoir characterization What is real reservoir capable of performing? Lack of integrated geologic, reservoir, and performance data Coupled reservoir simulation, i.e., reservoir, wellbore pipeline, facilities Lack of suitable reservoirs (new reservoirs) Lack of quality data Damaged reservoirs (wells)	Geographical locations of suitable reservoirs Limited in new projects by available quality depleted gas reservoirs Some technology options are high risk Market uncertainty Difficulty valuing existing regulated assets Cushion gas cost	Lack of methodology to accurately (and economically) measure stress (delta-pressure)	Strength of materials and regulatory limits on safe operations practices Need models for entire system No strength of materials models for existing wells Age of existing facilities—limits the options available to re-engineer asset Aging infrastructure originally designed for seasonal service Surface and pipeline constraints Pipeline capacity from storage "island" to the market Lack of flexibility of field/well operations	The legacy of regulation Regulatory uncertainty Utilities lack incentives Lack of regulatory clarity for shifting assets out of regulation Reservoir pressure limitations—limited in most states by discovery pressure	Concise collaborative technology initiative Limited technical manpower talent Technology not up with the times Lack of technology man hours (for simulation) Technology transfer

Exhibit 2-2. CONVENTIONAL GAS STORAGE—GROUP B: What are the R&D Opportunities/Needs to Overcome the Barriers?

Most Critical R&D Needs: ✪ = High Priority Vote ● = Priority Vote

Timeframe	Education and Technology Transfer	Existing Facility Optimization	Regulation	Reservoir Characterization	New Technologies
SHORT-TERM (0-5 YEARS)	Other - encourage/ foster closer government/industry technology research initiative ●●●●● Educate U.S. consumer, business, government, and financial world on storage industry, regulations, and barriers DOE to act as liaison with regulators to reinforce industry opinions on the safety of underground gas storage practices DOE to continue to serve as collaborative technology forum to bring storage operators together with research initiatives	Automated field operating systems ●●●●●●●● Research into geo-mechanical predictive mechanisms in conventional gas storage reservoirs ✪●● Identify the right data to collect (identify performance drivers) ●●● Reengineering of baseload fields for higher value services ●●● Develop technologies that allow for re-entry into existing well bore for recompletion in a better quality area of reservoir ●● Develop cost-effective method to produce gas/water in aquifer storage	Storage industry task force on deregulation ●●● Perform risk assessment analysis EH&S ●●	Better coupled reservoir/surface simulators ●●●●●● Evaluate current reservoir capacity and deliverability ✪✪✪ Permanent geophysical monitoring ✪●●● Integrated geophysics and reservoir modeling ●● Develop simple, quick, integrated data analysis methods ● Develop cost-effective data collection strategy ●	Integrity: Develop advanced casing inspection tools capable of characterizing pipe condition ✪✪✪✪● Develop new methods for creating storage reservoirs ✪✪✪● Market Uncertainty/ Risk: Develop tools/products to evaluate base gas alternatives (lower cost) ●●●● – Use of inert cushion gas Integrity: Develop methods to accurately calculate stress from existing logs ✪ Research suitability of unconventional reservoirs (i.e., deep, fractured) ● Improved data management system ● Develop new technology to assist engineers and managers make better decisions – Lined rock cavern for areas with no salt or reservoir Improve methods for inventory verification
MID-TERM (5-10 YEARS)			Redesign regulatory framework ●●	Permanent geophysical monitoring ✪●●●	Utilize hydrates as storage medium
LONG-TERM (10-15 YEARS)					New methods for brine disposal and use ●

Exhibit 2-3. CONVENTIONAL GAS STORAGE—GROUP B: Implementation Strategy

R&D Priority	Component R&D Activities and Steps	Capabilities, Tools, Facilities, and Resources	Collaborations, Partners, Government Role	Geographic Benefits	Impact (0-5)
#1 Integrity: Develop advanced casing inspection tools capable of characterizing pipe condition	Evaluation of current tools Evaluation of integrity of multi-concentric strings Further development of current tasks Design parameter characterization Develop correlations between log interpretations to strength of materials to determine well-bore integrity	Oil Field Service Co—have ability to do tool research Southwest Research Battelle Gaz de France	Service companies (Tool development lead) Operators (lead) Laboratories (lead) University American Petroleum Institute Interstate Oil & Gas Compact Commission (IOGCC) ASME SPE – Society of Petroleum Engineers Collaboration Types – Joint research ventures – Committees Government Role – Organize – $ – Technology transfers – Facilitate	Everywhere	Deliverablity/Cycling = 4 Cost Savings = 4 Safety and Security = 5 Capacity = 0 Environmental = 4.5 Reliability = 4

Exhibit 2-3. CONVENTIONAL GAS STORAGE—GROUP B: Implementation Strategy

R&D Priority	Component R&D Activities and Steps	Capabilities, Tools, Facilities, and Resources	Collaborations, Partners, Government Role	Geographic Benefits	Impact (0-5)
#2 Develop new methods for creating storage reservoirs	Continue work on lined rock caverns Regional geologic feasibility cost benefit studies Thermal re-excavation New aquifer methods New sealing methods Cost reduction (liquefaction) Abandoned coal mines Higher Btu content	Sandia National Lab Geological societies (USGS) Universities AAPG Service companies DOD drilling techniques ARMA A&E Co. API for Btu	USGS State geological societies University Service companies Operating companies Construction companies Joint research ventures Conservation Joint business ventures State agencies Government Role – $ – Research – Coordination – Technology transfer Government leads with USGS	New England Mid-Atlantic South East Creates a new "everywhere"	Deliverablity/Cycling = 1 Cost Savings = 1 Safety and Security = 0 Capacity = 1 Environmental = 1 Reliability = 2.5
#3 Evaluate current reservoir capacity and deliverability	Quantify effect of damage on deliverablity Impacts of lost gas Identify source of damage Geomechanical integrity Optimize reservoir performance Advanced data interpretation Update/advance reservoir characterization	Service companies Universities Consultants Operators Sandia National Labs Tool well test analysis Geologic reservoir models Reservoir simulation Artificial intelligence Methods of advanced data collection	DOE Private industry Operators Consultants Universities Labs Government Role – None? – $ – Coordination – Technology transfer	Everywhere (new and old)	Deliverablity/Cycling = 5 Cost Savings = 5 Safety and Security = 1.5 Capacity = 5 Environmental = 3 Reliability =5

Exhibit 2-3. CONVENTIONAL GAS STORAGE—GROUP B: Implementation Strategy

R&D Priority	Component R&D Activities and Steps	Capabilities, Tools, Facilities, and Resources	Collaborations, Partners, Government Role	Geographic Benefits	Impact (0-5)
#4 Automated field operating systems	Survey existing practices Cost effective instrumentation Communication technology Data storage/management Data integration Data mining and analysis Artificial intelligence Scope = include pipeline to reservoir Maintenance and reliability of existing systems	Service companies Implementation firms Software data developers Industry Process control Communication companies Demonstration sites	Industry Service companies Operators Consultants Universities Labs Software companies Instrumentation people Collaboration Types – Develop technology – Collaborative/Cooperative agreements Government Role – Technology transfer – Coordination – $	Everywhere	Deliverablity/Cycling = 3 Cost Savings = 4 Safety and Security = 5 Capacity = 0.5 Environmental = 2 Reliability = 5

Section III
Gas Storage for Power Generation

Exhibit 3-1. GAS STORAGE FOR POWER GENERATION: What are the Barriers to Improve Gas Storage for Power and Remote Off-Pipeline?

Injectability Cycling	Regulatory	Capital Risk	Remoteness and Location	Technical Risk
Injectability larger problem than deliverability especially conventional storage reservoirs – Especially Rocky Mountain and northeast Pad gas and working gas – Reduce ratio – Inert gas – Recovery Storage gas cycling for delivery to power generating facilities/gas injection Flexibility—injection/withdrawal at short notice—controls Counter cycling service/reservoir inventory management Reliability The storage needs for peakers different from baseload plants Downstream deliverability of available capacity Balancing power peak requirements with upsets "nominations"	Barrier, no regulatory incentive! – Easiest projects cannot be done – Especially utilities with basic engineering Air emission limitations limits injection compressor emissions Pipeline use: – Cost allocation – Industries subsidize IPP's, LDC's Delta pressuring to increase working capacity—regulatory restrictions Public acceptance "NIMBY," regulatory impediment Relative environmental impact (CO_2)	Regulatory – capital risk allocation – independent merchant has no rate base to absorb mistakes Reservoir evaluation – staging risk Risk market will overbuild due to regulatory impediments Market liquidity during high demand periods – "it is not available"	Remoteness itself is a barrier. It is economic risk. Security vs. terrorism sensitivity of storage medium Good DG sites usually off-pipeline	Salt cavern brine disposal Geologically constrained areas "no or low deliverability" Resource conservation/loss (shrinkage) Is there a role for onsite LNG storage at power plants? Regulatory, technology, economic barriers – Trucking and liquefaction on site Personnel – Training – Experience – Education – Commercial savvy

Exhibit 3-2. GAS STORAGE FOR POWER GENERATION:
What are the R&D Opportunities/Needs to Overcome the Barriers?

Most Critical R&D Needs: ✪ = High Priority Vote ● = Priority Vote

Timeframe	Injectability Cycling	Regulatory	Capital Risk	Technical Risk	Remoteness and Location	Environmental Restrictions
NEAR-TERM (0-5 YEARS)	Research into well completions, fracturing, reservoir engineering, better simulation techniques ✪✪●● Research into better control mechanisms to enhance flexibility ✪ Alliance with engine/compressor manufacturers for cycling units ● Non-damaging compressor lubricants	Expedited or elimination of FERC 7C relative to risk ✪✪●●●● Economic benefit to power consumers with enhanced storage infrastructure ✪✪●● National asset reevaluation ●● R&D can show magnitude of the engineering opportunity ● Downhole safety valves “screwed” ● Electric Motor Drive (EMD) at storage exempt from power curtailments on interruptible (IT) contracts Research into improved operational efficiency and technologies that preserve national resources	Commercial optimization ●●●	Long-term integrity of bedded salt caverns information ✪✪✪● Cement quality, bond quality, pipe quality ●●● – Longevity/safety casing and well-bore design Brine disposal alternatives and opportunities – increase saturations during leeching ●● LNG vaporization technology Focus especially operations/tools to storage development	CNG and other solutions ✪●●●●● Better ways to look inside salt ●●●● Facility safety/security report ● Distributed generation vs. central station infrastructure requirements R&D	Compressor environmental performance Risk of SCR application to gas storage
MID-TERM (5-10 YEARS)	Variable speed compressor ●●		Other value added solutions, e.g., cogeneration ●● Better and cheaper reservoir modeling	Gas cleanup for H_2O/CO_2 in LNG process and gas liquids	Novel R&D ✪●● New, tools for cheap screening new formation ●● Distributed Generation R&D must include storage options ●● Assessment of underground reservoir traps	Gas migration assessment and abandonment ●●
LONG-TERM (10-15 YEARS)				Use of inert gas for PAD gas ●●●		

Exhibit 3-3. GAS STORAGE FOR POWER GENERATION: Implementation Strategy

R&D Priority	Component R&D Activities and Steps	Capabilities, Tools, Facilities, and Resources	Collaborations, Partners, Government Role	Geographic Benefits	Impact (0-5)
#1 Long-term geotechnical integrity of bedded salt caverns, e.g., roof leaks, deformation	Geologic analysis Failure analysis and definition Monitoring feedback for better front end	Casing design E&P tool, lab tests, database raise it to a safety issue	Among industry SMRI, GTI, DOE/SPR, NYSERDA, academia, government-public meetings	Appalachia, Canada, Central Mid-West, Northern Mexico	Deliverablity/Cycling = 1.5 Cost Savings = 3 Safety and Security = 5 Capacity = 5 Environmental = 4 Reliability = 5
#2 CNG and other solutions, remote application needle peak, DG support	Demonstration Marketing feasibility study Regulatory support Security aspect education	Equip designers, end-users, pilot plant	Storage developer and power generator and end user industry Government-regulatory standards and funding	Anywhere in rural and urban downtown Double pipeline capacity downtown and coastal urban – Feed both ends of loop	Deliverablity/Cycling = 5 Cost Savings = 1 Safety and Security = 2 Capacity = 1 Environmental = 4.5 Reliability = 5
#3 Expedited or elimination of FERC 7C relative to risk	Independent study Experimental well by the operator/risk taker Assessment of opportunity and risk	Education and workshop E&P tools Active role by service companies	E&P and service companies and storage operator State government, EPA	Everywhere. Good for salt and reservoir	Deliverablity/Cycling = 4.5 Cost Savings = 3.5 Safety and Security = 2 Capacity = 5 Environmental = 1 Reliability = 4
#4 Research into well completions, fracturing, reservoir engineering, better simulation techniques for injectivity timing	Apply E&P tools to study going other way for injection. Focus on storage vs. production. Reservoir engineering model	Use existing field for pilot studies Reservoir engineering model match	Storage operators and service and E&P State regulators, and EPA	Anywhere reservoir storage	Deliverablity/Cycling = 5 Cost Savings = 3 Safety and Security = 1 Capacity = 4 Environmental = 1 Reliability = 4.5
#5 Economic benefit to power consumers with enhanced storage infrastructure replace long-haul firm transport (FT)	Sensitivity analyses Demonstration at peaker and CC Review existing studies	Models (fuel) – Pipeline – Dispatch – Storage Result is economic model showing optimization for commodity and transportation	ISO regional studies OED at FERC (Office of Economic Development) Pipeline and storage companies	Any marketing company in U.S. Any IPP	Deliverablity/Cycling = 1 Cost Savings = 3.5 Safety and Security = 0 Capacity = 3.5 Environmental = 1 Reliability = 2.5

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